Determination and Evaluation of Select Metal Ions from Olentangy River Water

A senior thesis in partial fulfillment of the requirement for the degree of Bachelor of Science

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Abstract

Seventeen water samples were collected from October 12 to December 15, at a single location on the Olentangy River, at intervals of approximately one sample every four days.

These samples were analyzed for their content of the elements, Ca, Mg, K, Sr, Cd, Mn and Zn, by Atomic Absorption methods.

Discharge and temperature conditions were also monitored over this period of time.

The concern of this report was to understand the manner in which the metal ions, in the water samples, varied, rather than the empirical amounts of metal concentration, or of where the metal concentration stand in view of government pollution standards.

Evaluation of the data followed the analysis of the samples. A correspondence between concentration and discharge produced an inverse relationship, where by metal concentration would decrease as discharge increased. Correspondence between concentration and temperature revealed a weakly supported direct relationship where by, an increase in temperature would spur a slight increase in concentration.

Introduction

The metallic constituents of river water and the manner in which variations of these constituents occur, are a concern of those involved with public water suppies, hydrology and geochemistry.

Variations of concentrations among the metallic constituents of river water are of special interest because of the potential adverse effects trace amounts of metals have upon the physiological well being of life.

This project directs it's focus to the manner in which metallic constituents of river water vary over a given period of time. Water samples were gathered from a single location on the Olentangy River for the purpose of quantitatively analyzing for the metals, Ca, Mg, K, Sr, Cd, Mn, and Zn. Water from the Olentangy River was selected for the subject of this paper, because of the river's close proximity to Ohio State University and because of the accessability to discharge information from the U.S.G.S. gaging station located up stream from Ohio State University near Worthington, Ohio.

River conditions were also monitored over this period of time in hope of correlating relationships to explain the changes, or lack of changes in metal concentrations of the river water.

The water samples were analyzed for both light metals (Alkali and Alkaline Earth metals) and heavy metals (transition series) by means of Atomic Absorption flame spectrophotometry.

The water samples were collected approximately every 4 days (4.125) over the period commencing on October 12 and ending on December 15, 1978.

Temperature data was provided by the U.S.G.S. Although this data was acquired from a gaging station on the Scioto River, south of the junction of the Olentangy and Scioto Rivers, at Shadeville, Ohio, the temperatures should be approximately the same as those for the Olentangy.

Collection and treatment of samples

Seventeen samples of Olentangy River water were collected during the period of October 12 to December 15. The foot-bridge over the Olentangy River, adjacent to the O.S.U. Drake Union, provided the site for sampling. A 250 ml. beaker, suspended by string and rubber bands was used to gather the water from a position above the middle of the channel.

The beaker was lowered and submerged to a depth of about 1/2-1 foot above the river bottom, then slowly reeled up. Part of this water was used to doubly rinse the polyethylene bottles, while the remaining contents of the beaker were poured into the rinsed bottle.

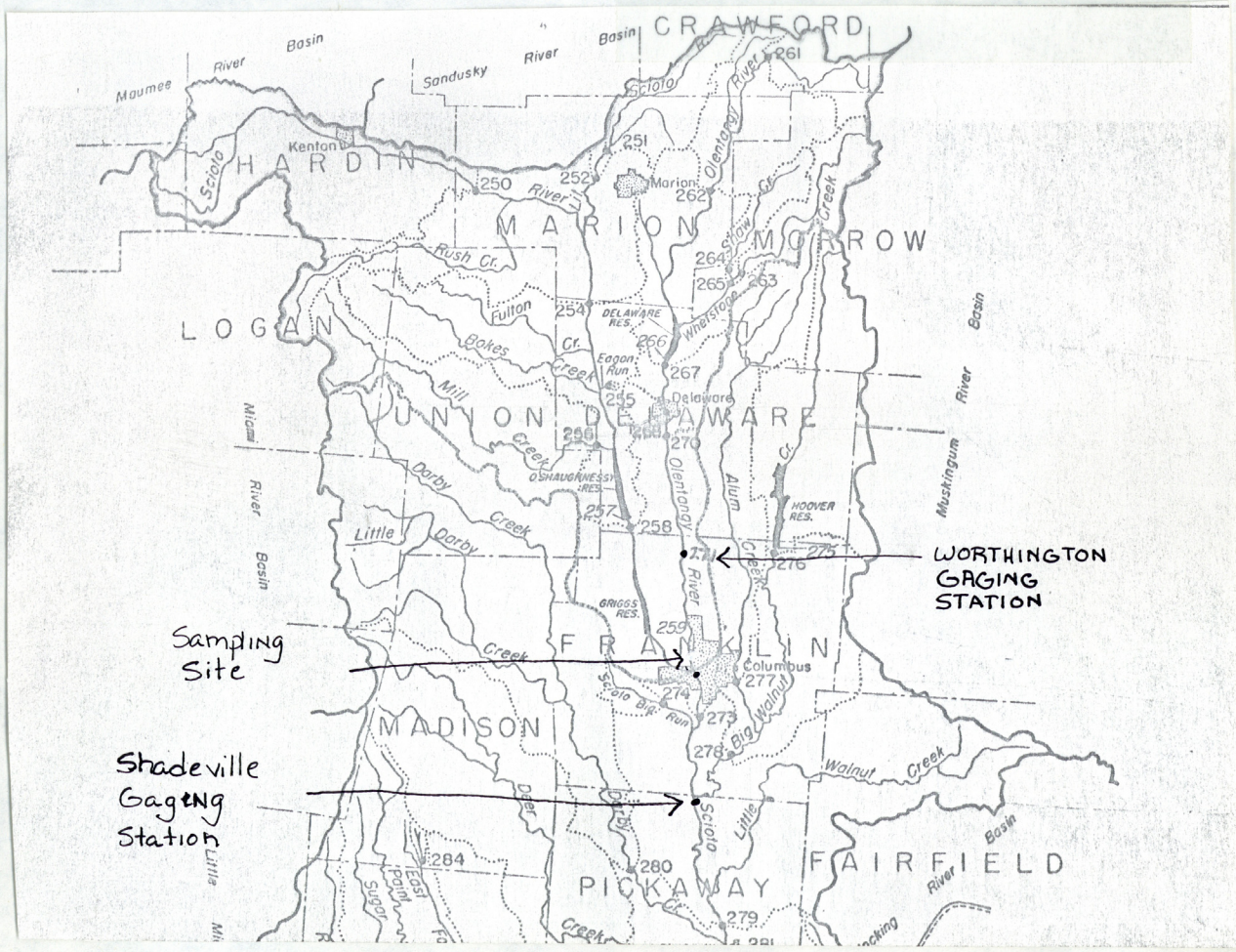
A 20 ml. portion from each of the 17 samples was diluted with 98 ml. of demineralized and doubly distilled water, and 2 ml. of dilute HNO_3. These dilute samples were necessary to insure accurate measurement of certain metals with fairly high concentrations. In atomic absorption, metal concentrations that are greater than an experimentally calculated linear working range, are quantitatively exaggerated but can either be logarithmically recalculated, or the original samples can be diluted down to the confines of the linear working range. The latter method was chosen because of the simplicity of dilution and the luxury of an abundant amount of samples to work with.

The very small amounts of HNO_3 (less than .8%) were added to insure the dissociation of metallic ions in solution.

The results of analysis of the dilute water samples were simply multiplied by a factor of 5 to compensate for the 5 fold dilution.

The original, non-diluted samples, were left untreated.

Sampling site



Data Stations.
(from Eastin, 1967)

Atomic Absorption

Atomic Absorption Spectrophotometry as an analytical technique was first introduced by Walsh in 1955.

The basis of atomic absorption relies on the fact that atoms in an unexcited state will become excited when bombarded with a beam of light, of a prescribed wavelength, which is characteristic of the type of atom being analyzed. The excited state results from the absorption of some of the radiant energy by the atom itself. The amount of radiation absorbed is proportional to the number of atoms of the particular element present.

Volborth (1969) designates the essential parts of an Atomic Absorption Spectrophotometer to be the hollow cathode lamp, an atomizing system, a burner, a monochromator, and a photodetector.

The hollow cathode lamp provides the source for the radiant energy. The sample is aspirated into the beam of light in the form of a flaming, acetylene - air - sample mixture. If the atoms, being searched for, are present in this mixture, they will respond to the radiant energy given off by the cathode lamp, by absorbing a small fraction of the light beam.

The slightly diminished light will then enter the monochromator, which filters out any light other than that characteristic of the element being searched for.

The quantitative aspects of this process are realized when the light beam enters a photodetector, which measures the amount of light

received. Standard, known amounts of the particular element being searched for, are introduced to this process in order to calibrate the electronic read-outs which otherwise would be meaningless.

The particular atomic absorption spectrophotometer used for analysis in this project was a Perkin-Elmer model 303 (1970) which was accompanied by a Perkin-Elmer Digital Counter Readout (DCR).

During operation, each sample was automatically tested 4 times, then averaged by the read-out instrument. Further information may be obtained from "Instructions, Model 303, atomic absorption Spectrophotometer", bulletin 990-9415 of the Perkin-Elmer Company.

Olentangy Drainage Basin and the General geology of area

The Olentangy rises near Galion and flows at a low gradient for 40 miles to the southwest. Five miles above Delaware, the river enters a narrow gorge with a 6 feet per mile gradient. The Olentangy continues to flow 25 miles to the south towards it's final junction with the Scioto River at Columbus.

The Olentangy basin has an area of 536 square miles (Ohio Division of Water 1963).

The bedrock of the drainage basin is nearly flat lying sedimentry rock dipping gently to the east.

Bedrock of Devonian age outcrops over most of the basin. These rocks form the Columbus Limestone Fm., Delaware Limestone Fm., Olentangy Shale Fm., and Ohio Shale Fm., listed from oldest to youngest.

The Mississippian age shales and sandstones crop out in the extreme eastern part of the drainage basin. The Mississippian Bedford Shale comformably overlies the Devonian Shales. The Bedford shale is itself overlain by the Berea sandstone and shales, which are deltaic in origin.

Table (1) on the following page describes the maximum thickness and the character of the rocks.

The Columbus Limestone is the principle aquifer for farm and domestic wells. The Delaware Limestone may yield some groundwater,

From Rene Eastin

TABLE 1

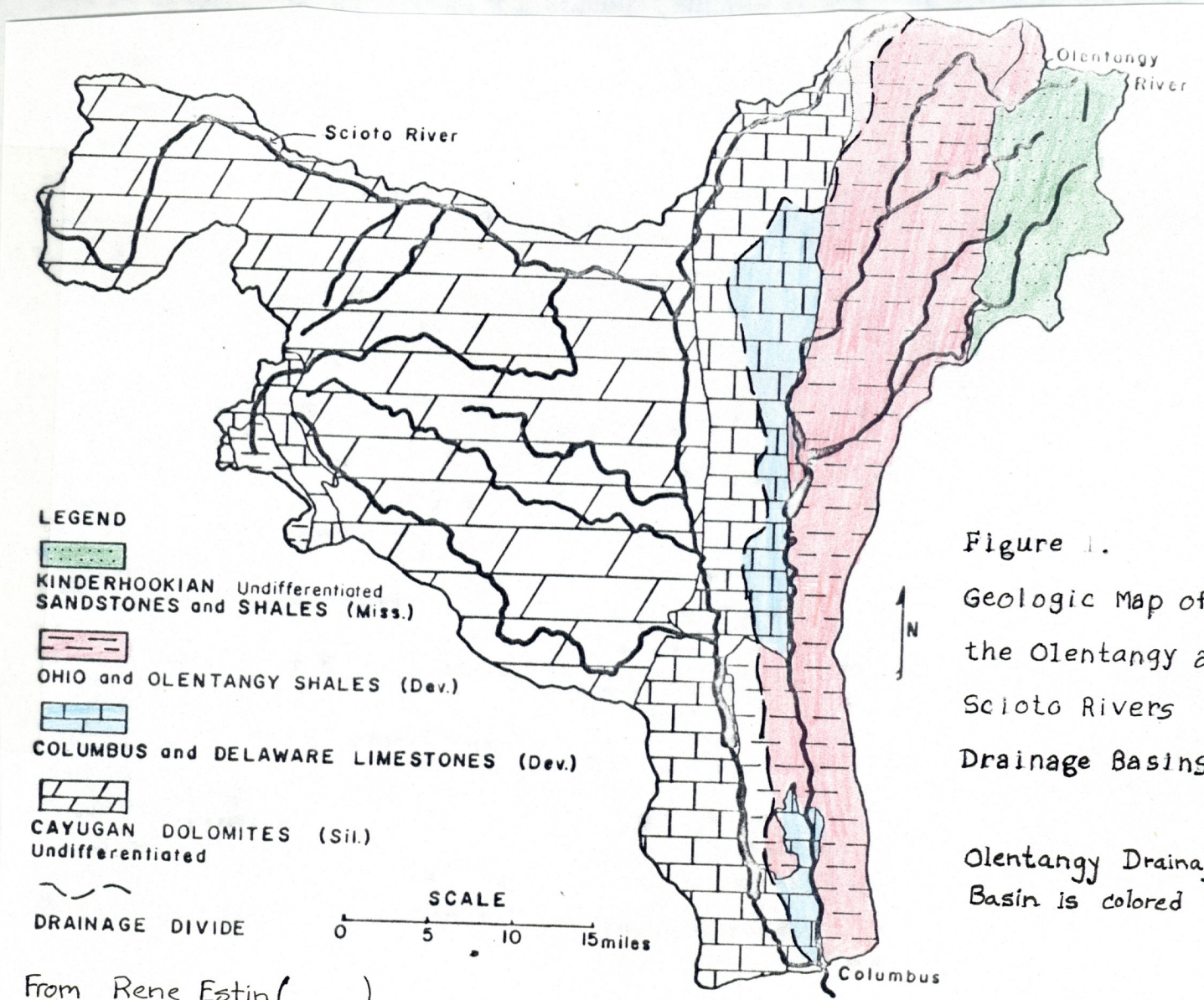
STRATIGRAPHIC SEQUENCE OF THE SURFACE ROCKS IN THE OLENTANGY AND UPPER SCIOTO RIVER BASINS

System	Series	Formation	Maximum Thickness (feet)	Character of Rocks	Ground-Water Yield
Mississippian	Kinderhook	Berea sandstone	60	Massive, gray to buff sandstone.	up to 25 gpm
		Bedford shale	90	Gray and brownish-red shale.	none
Devonian	Chautauquan Senecan	Ohio shale	450	Black or dark brown carbonaceous shale. Massive to thinly laminated.	none
	Erian	Olentangy shale	30	Soft, argillaceous, blue-gray shale.	none
		Delaware limestone	40	Thin-bedded, blue-gray, cherty limestone	up to 3 gpm
	Ulsterian	Columbus limestone	105	Brown, dolomitic limestone grading up into massive, fossiliferous, gray limestone.	up to 175 gpm

while the Ohio and Olentangy Shales contain little or no groundwater. The Berea Sandstones are the only Mississippian rocks which yield groundwater in the Olentangy basin (Schmidt 1958).

An average of 50 feet of glacial till covers the bedrock. The till plains are almost flat to gently rolling. These unconsolidated deposits were brought down from the northwest during various Pleistocene glacial fluctuations. Other glacial deposits include end moraines, eskers, Kames and outwash deposits.

Recent Alluvium is also present in the drainage basin, but does not occur in abundance.



From Rene Estin( )

Figure 1.
Geologic Map of the Olentangy and Scioto Rivers Drainage Basins.

Olentangy Drainage Basin is colored

ELEMENT: Sr

Color of air-acetylene flame: lean blue

Concentration of standards (ppm): 2.0 : 1.0 ; .5

Noise suppression: 2

Slit setting: 3

Wavelength: 230 VIS.

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	1.10	11-22:	1.7
10-18:	1.75	11-26:	1.8
10-22:	2.05		
10-25:	1.55	12-1 :	1.45
10-30:	1.1	12-5 :	1.45
		12-7 :	1.25
11-6 :	1.8	12-10:	1.15
11-13:	2.35	12-12:	1.45
11-16:	1.9	12-15:	1.2
11-19:	.65		

ELEMENT: Ca

Color of air-acetylene flame: Lean Blue

Concentration of standards (ppm): 2.0 ; 1.0 ; .5

Noise suppression: 2

Slit setting: 4

Wavelength: 211 VIS

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	55.50	11-22:	54.3
10-18:	54.55	11-26:	57.4
10-22:	56.3		
10-25:	59.0	12-1 :	59.75
10-30:	62.75	12-5 :	51.35
		12-7 :	55.3
11-6 :	63.05	12-10:	52.0
11-13:	68.05	12-12:	60.1
11-16:	47.05	12-15:	52.15
11-19:	45.2		

ELEMENT: K

Color of air-acetylene flame: lean Blue

Concentration of standards (ppm): 3.0 ; 2.0; .5

Noise suppression: 2

Slit setting: 4

Wavelength: 383 Vis

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	6.8	11-22:	6.5
10-18:	6.5	11-26:	6.1
10-22:	6.3		
10-25:	6.6	12-1 :	6.35
10-30:	6.7	12-5 :	6.25
		12-7 :	5.6
11-6 :	6.95	12-10:	5.55
11-13:	7.25	12-12:	6.15
11-16:	6.5	12-15:	6.05
11-19:	5.8		

ELEMENT: Mg

Color of air-acetylene flame: lean Blue

Concentration of standards (ppm): 2.0 ; 1.0 ; .5

Noise suppression: 2

Slit setting: 4

Wavelength: 285 UV

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	13.9	11-22:	14.3
10-18:	14.25	11-26:	14.45
10-22:	13.8		
10-25:	14.6	12-1 :	14.85
10-30:	14.7	12-5 :	12.75
		12-7 :	13.65
11-6 :	15.6	12-10:	12.15
11-13:	15.86	12-12:	12.75
11-16:	12.15	12-15:	13.6
11-19:	11.6		

ELEMENT: Cd

Color of air-acetylene flame: lean Blue

Concentration of standards (ppm): 2.0 : 1.0 : .5

Noise suppression: 2

Slit setting: 4

Wavelength: 229 UV.

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	.02	11-22:	.04
10-18:	.04	11-26:	.02
10-22:	.04		
10-25:	.02	12-1 :	.03
10-30:	.02	12-5 :	.04
		12-7 :	.04
11-6 :	.02	12-10:	.04
11-13:	.04	12-12:	.04
11-16:	.02	12-15:	.03
11-19:	.03		

ELEMENT: Zn

Color of air-acetylene flame: lean Blue

Concentration of standards (ppm): 2.0 : 1.0 ; .5

Noise suppression: 2

Slit setting: 4

Wavelength: 214 UV

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	.13	11-22:	.15
10-18:	.15	11-26:	.14
10-22:	.10		
10-25:	.20	12-1 :	.12
10-30:	.23	12-5 :	.16
		12-7 :	.17
11-6 :	.15	12-10:	.16
11-13:	.16	12-12:	.12
11-16:	.15	12-15:	.20
11-19:	.12		

ELEMENT: Mn

Color of air-acetylene flame: lean blue

Concentration of standards (ppm): 2.0 ; 1.0 ; .5

Noise suppression: 2

Slit setting: 3

Wavelength: 279 UV

CONCENTRATION OF SAMPLES

Measurements recorded in parts per million.

10-12:	.05	11-22:	.06
10-18:	.08	11-26:	.07
10-22:	.08		
10-25:	.10	12-1 :	.05
10-30:	.04	12-5 :	.07
		12-7 :	.07
11-6 :	.09	12-10:	.06
11-13:	.05	12-12:	.06
11-16:	.10	12-15:	.11
11-19:	.13		

Complete Discharge Record of Olentangy River

Discharge record from Oct. 14 through Dec. 15.
Data received, courtesy of U.S.G.S., Columbus, Ohio.
Gaging station located near Worthington, Ohio.

Discharge in cubic feet per second.

Date	Discharge
10-14	49
10-15	47
10-16	38
10-17	38
10-18	34
10-19	36
10-20	37
10-21	33
10-22	33
10-23	34
10-24	37
10-25	36
10-26	37
10-27	51
10-28	43
10-29	38
10-30	39
10-31	41
11-1	38
11-2	38
11-3	38
11-4	38
11-5	38
11-6	39
11-7	40
11-8	40
11-9	39
11-10	37
11-11	37
11-12	37
11-13	40
11-14	84
11-15	97
11-16	75
11-17	73
11-18	90
11-19	79
11-20	59
11-21	58
11-22	56
11-23	61
11-24	64
11-25	57
11-26	57
11-27	62
11-28	63
11-29	78
11-30	104
12-1	82
12-2	57
12-3	96
12-4	249
12-5	315
12-6	129
12-7	117
12-8	367
12-9	605
12-10	179
12-11	82
12-12	105
12-13	2150
12-14	2010
12-15	1280

Complete Temperature Record

Temperature record from Oct. 12 through Dec. 15.

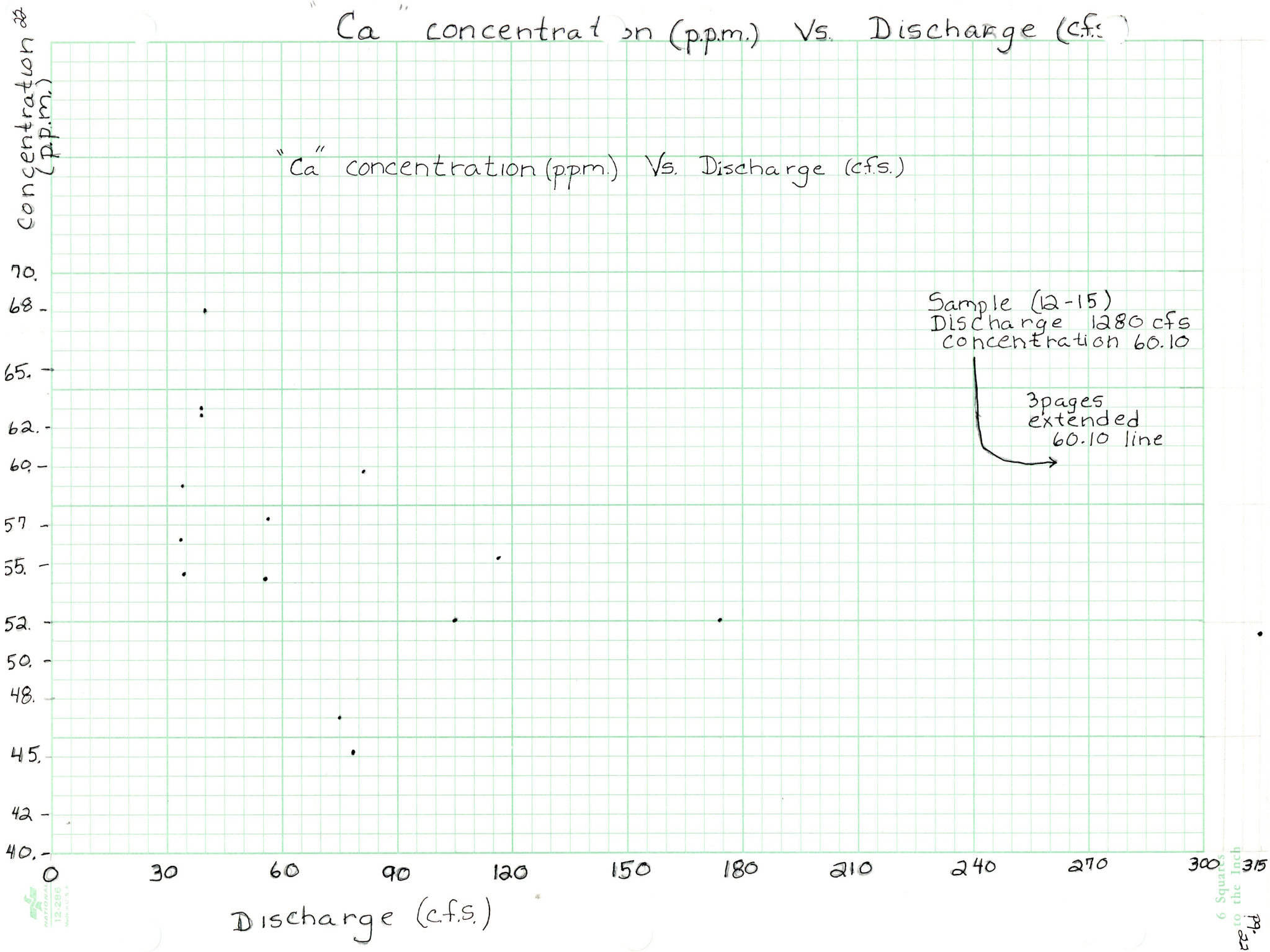
Data received, courtesy of U.S.G.S., Columbus, Ohio. Gaging station located on Scioto River, just after junction of Olentangy and Scioto Rivers, south of Columbus, at Shadeville, Ohio.

Temperature measured in degrees centigrade.

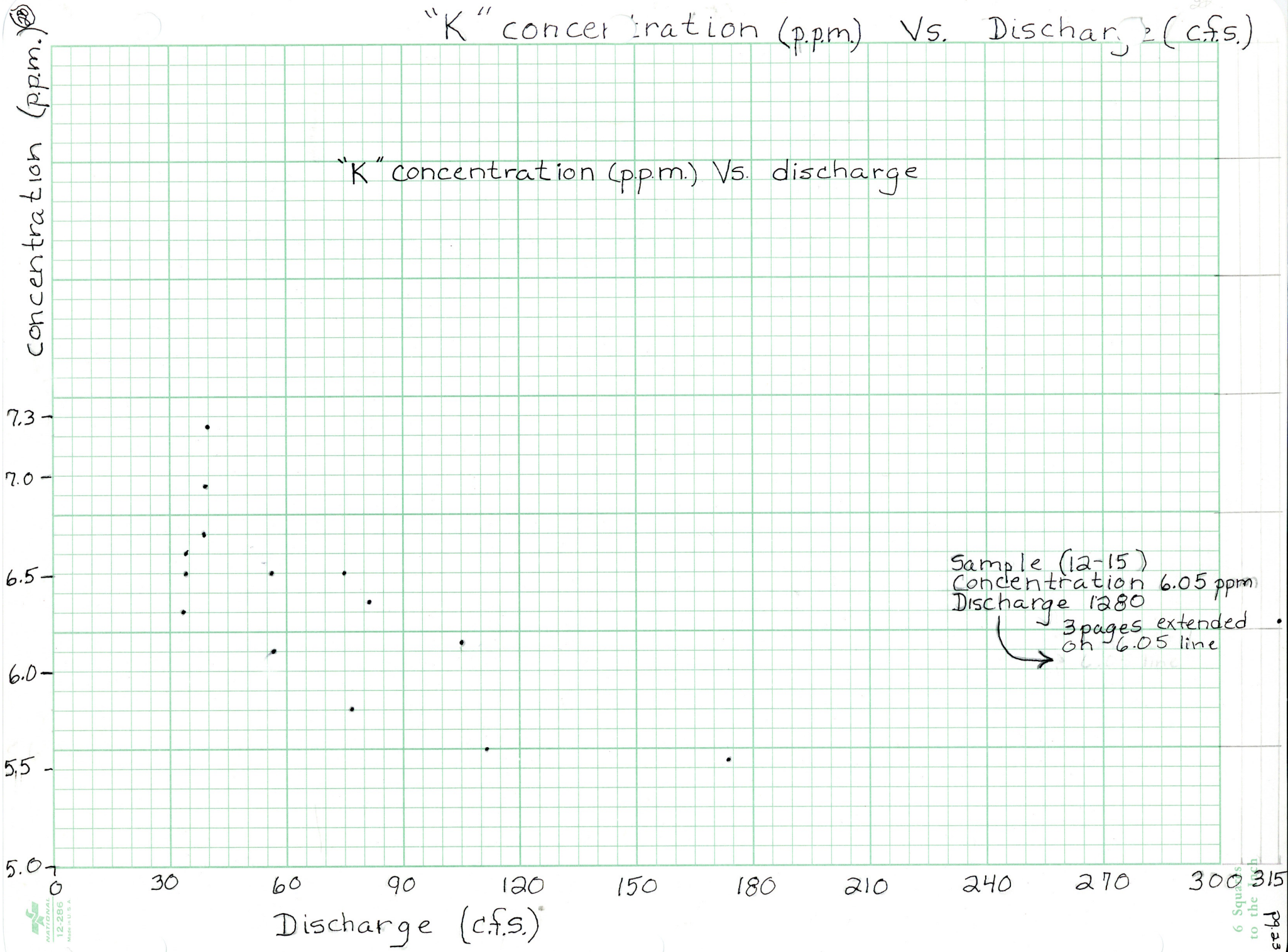
Temperature obtained by averaging max. and min. temperatures. (i.e.- max. 19.5 deg.; min. 17.5 deg.; ave. 18.5 deg.)

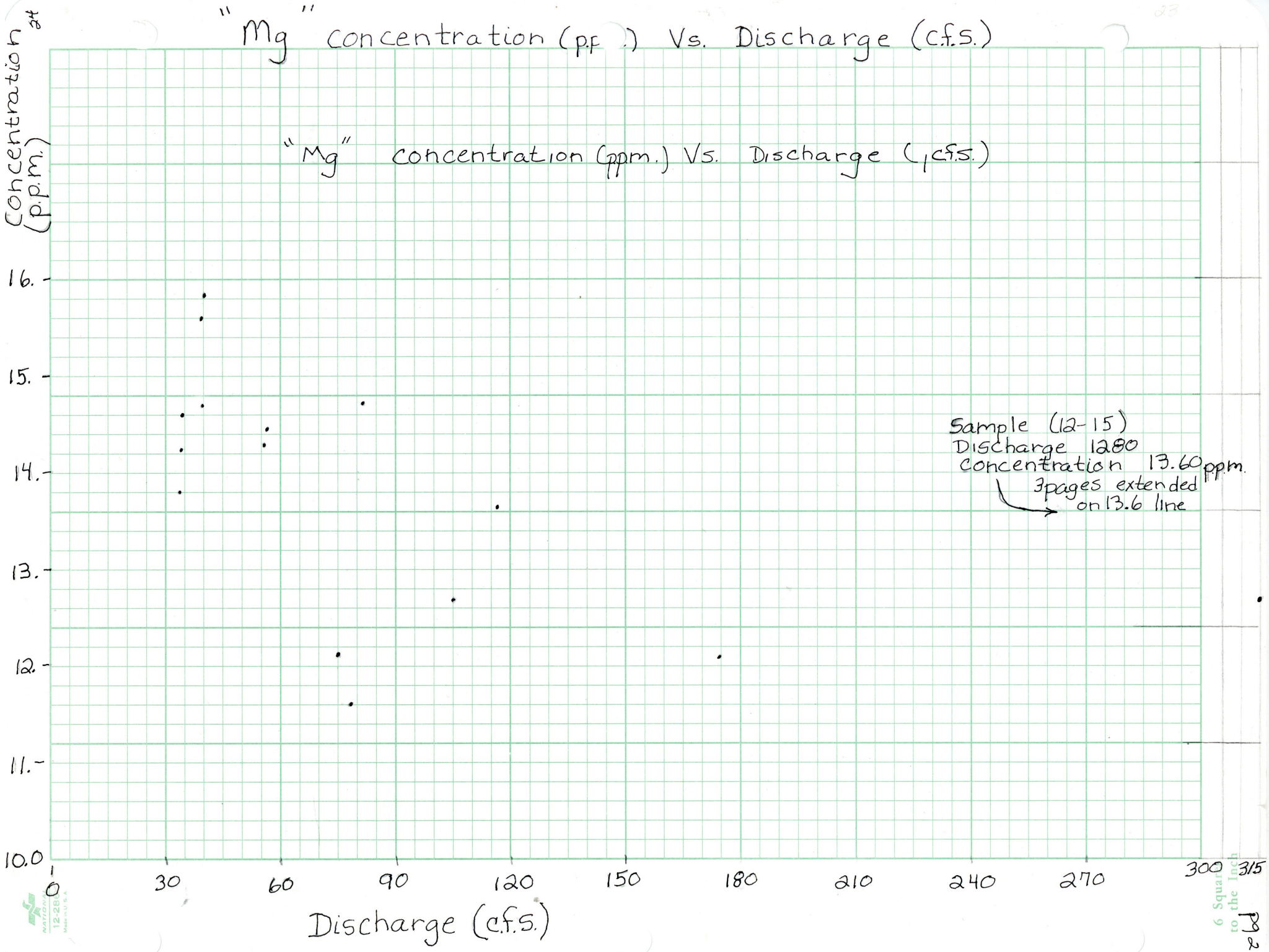
Date	Temp.
10-12	16.75
10-13	15.75
10-14	14.25
10-15	14.0
10-16	13.5
10-17	13.25
10-18	12.75
10-19	13.25
10-20	14.0
10-21	14.5
10-22	14.5
10-23	14.5
10-24	13.75
10-25	13.5
10-26	14.5
10-27	13.0
10-28	13.0
10-29	12.75
10-30	12.5
10-31	12.75
11-1	13.75
11-2	13.25
11-3	13.75
11-4	14.25
11-5	14.25
11-6	14.5
11-7	13.75
11-8	12.6
11-9	11.25
11-10	11.25
11-11	12.25
11-12	13.25
11-13	13.5

Data	Temp
11-14	13.25
11-15	12.25
11-16	11.75
11-17	12.75
11-18	11.5
11-19	10.5
11-20	10.5
11-21	10.25
11-22	10.5
11-23	11.5
11-24	10.5
11-25	8.25
11-26	8.25
11-27	8.5
11-28	7.0
11-29	5.75
11-30	6.25
12-1	6.5
12-2	6.75
12-3	8.5
12-4	7.75
12-5	6.5
12-6	6.5
12-7	7.5
12-8	7.75
12-9	5.25
12-10	3.0
12-11	3.25
12-12	4.5
12-13	4.25
12-14	3.25
12-15	3.0

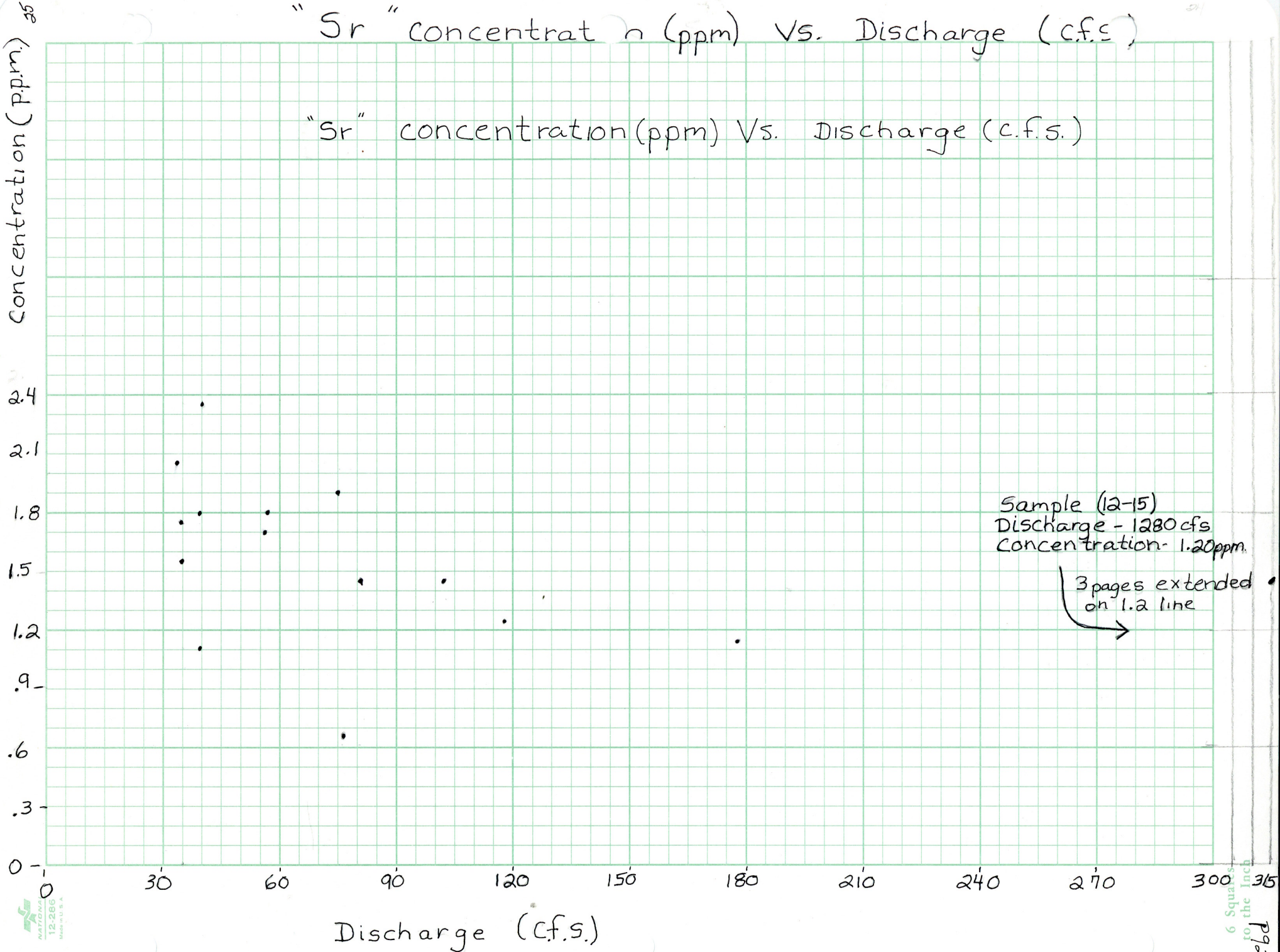

"Ca" concentration (p.p.m.) Vs. Discharge (c.f.s.)
Concentration "Ca" (p.p.m.)
70.
68.
65.
62.
60.
57
55.
52.
50.
48.
45.
42
40.
0
30
60
90
120
150
180
210
240
270
300
315
Discharge (c.f.s.)
Sample (12-15)
Discharge 1280 cfs
concentration 60.10
3pages
extended
60.10 line

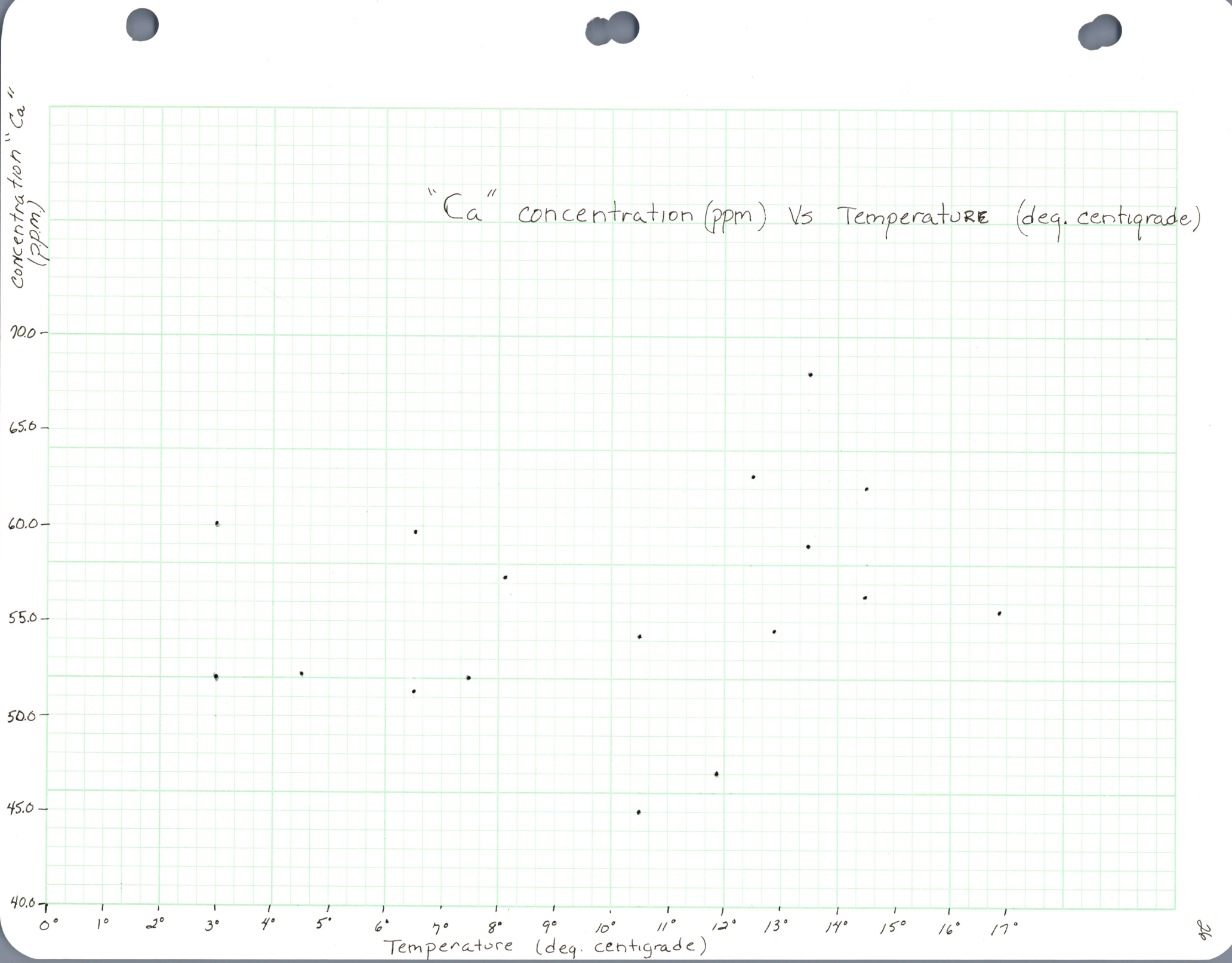
"K" concentration (p.p.m.) Vs. Discharge (c.f.s.)

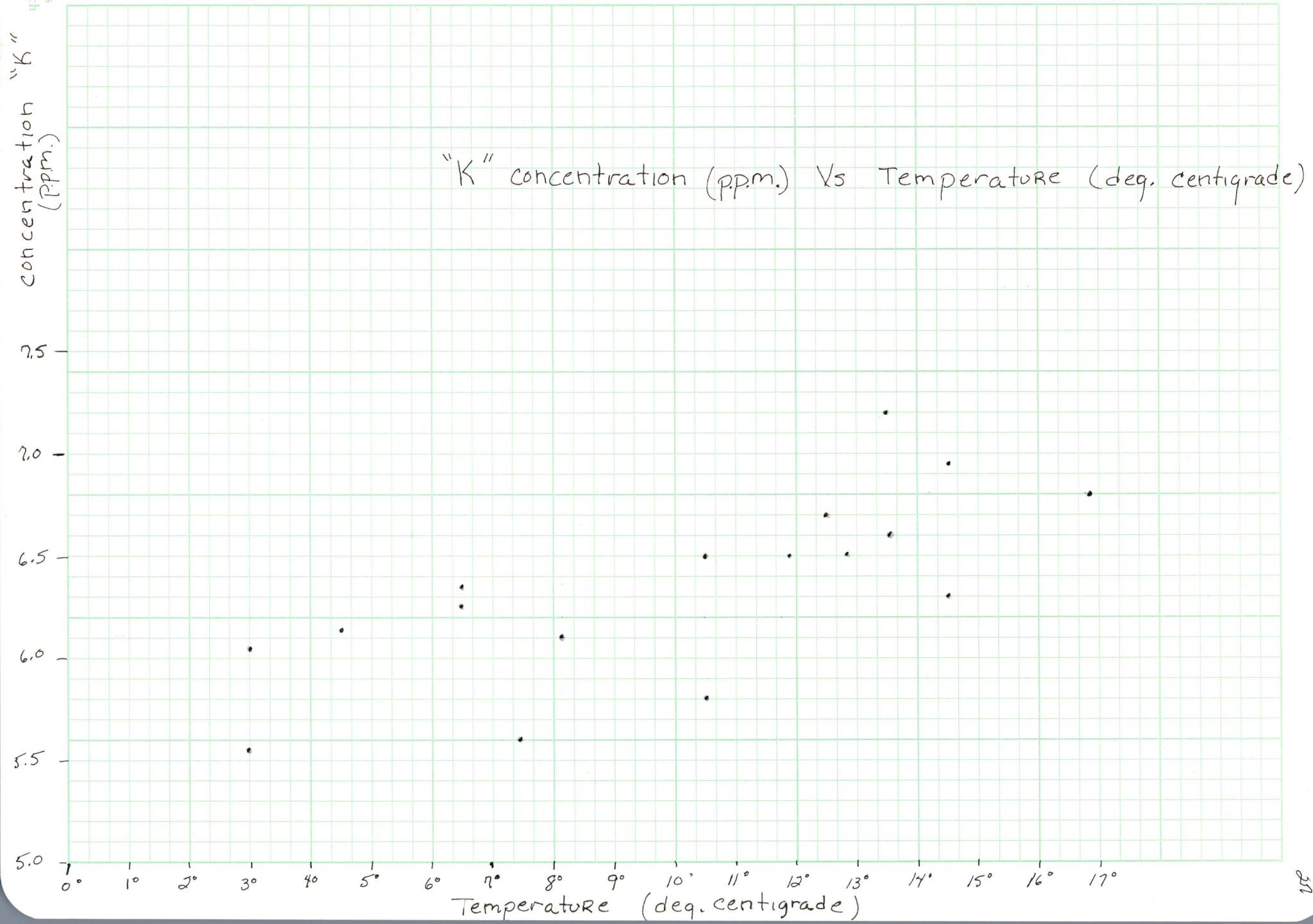


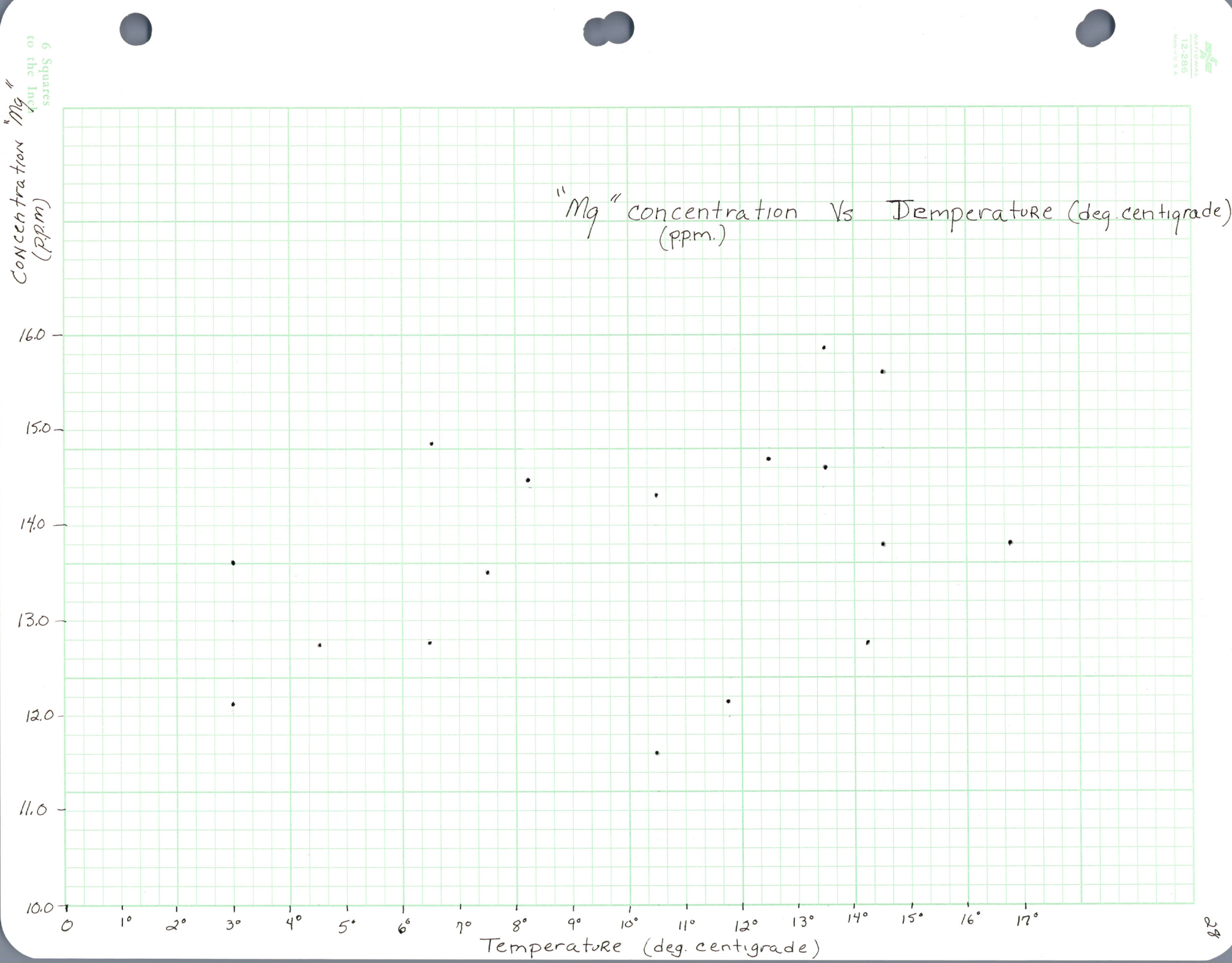

"Mg" concentration (ppm.) Vs. Discharge (c.f.s.)
"Mg" concentration (ppm.) Vs. Discharge (c.f.s.)
Concentration (p.p.m.)
16.
15.
14.
13.
12.
11.
10.0
Sample (12-15)
Discharge 1280
concentration 13.60 ppm.
3 pages extended
on 13.6 line
0
30
60
90
120
150
180
210
240
270
300
315
Discharge (c.f.s.)

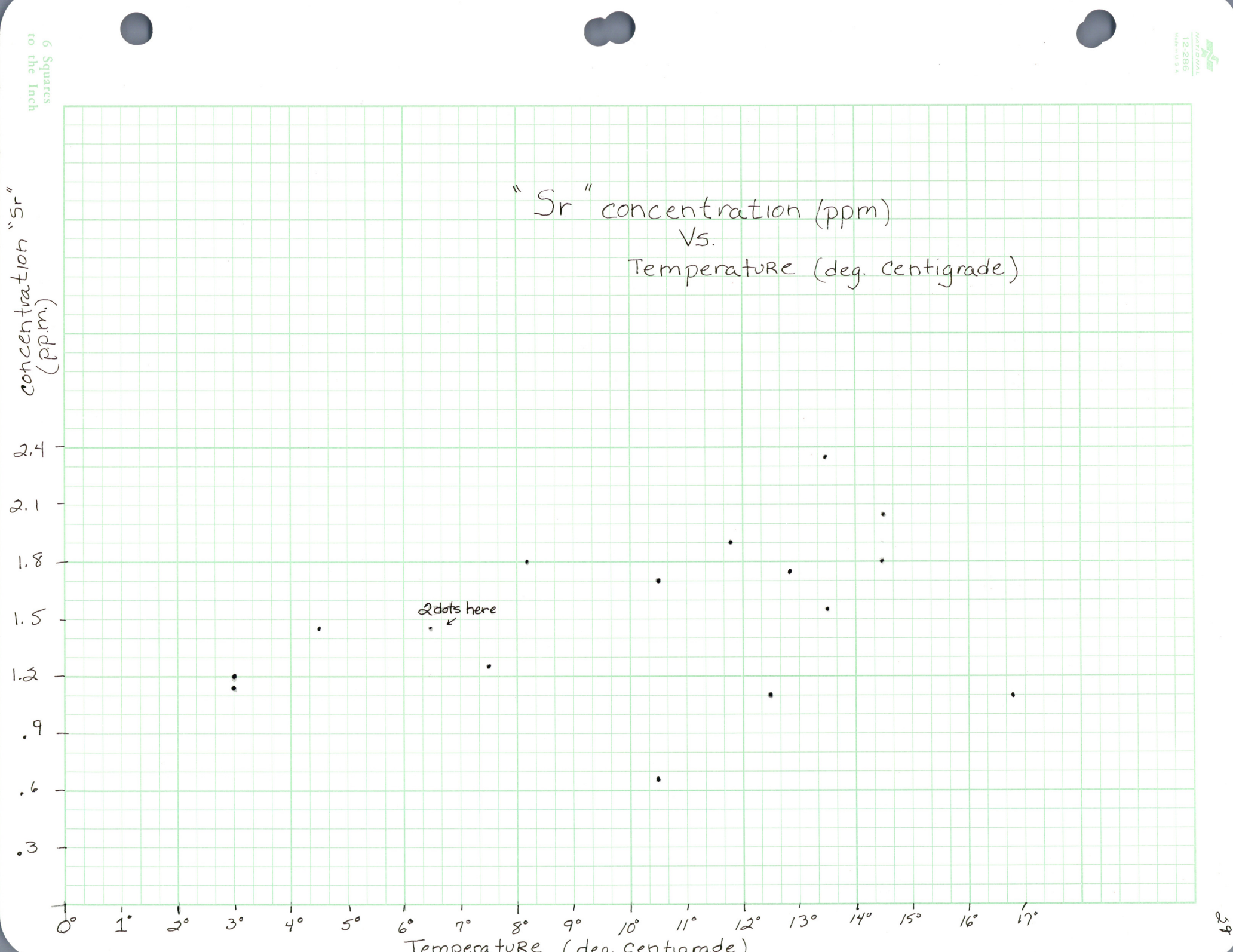
"Sr" concentrat n (ppm) Vs. Discharge (c.f.s)




"Ca" concentration (ppm) Vs Temperature (deg. centigrade)
concentration "Ca" (ppm)
70.0
65.0
60.0
55.0
50.0
45.0
40.0
0°
1°
2°
3°
4°
5°
6°
7°
8°
9°
10°
11°
12°
13°
14°
15°
16°
17°
Temperature (deg. centigrade)




"Mg" concentration Vs Temperature (deg. centigrade)
(p.p.m.)
Concentration "Mg" (p.p.m)
16.0
15.0
14.0
13.0
12.0
11.0
10.0
0
1°
2°
3°
4°
5°
6°
7°
8°
9°
10°
11°
12°
13°
14°
15°
16°
17°
Temperature (deg. centigrade)


"Sr" concentration (ppm)
Vs.
Temperature (deg. centigrade)
concentration "Sr" (p.p.m.)
2.4
2.1
1.8
1.5
1.2
.9
.6
.3
2 dots here
0°
1°
2°
3°
4°
5°
6°
7°
8°
9°
10°
11°
12°
13°
14°
15°
16°
17°
Temperature (deg. centigrade)

Man's Influence: How to deal with it

Metal elements in the environment are of two sources: those inherent in the bedrock and ground cover, and those contributed by man and his activities.

This report unfortunately does not deal with the contributions of man, or at best, assumes that the metal ion contributions of man were introduced to the environment at a near constant rate.

Because this report is mainly concerned with understanding the variations of metal concentrations, a near constant contribution of metal ions by man, would pose little problem in the evaluation of metal concentration data.

The assumption that man's metal contribution proceeds at a near constant rate can be somewhat supported by establishing cause-effect relationships between river conditions and metal concentration. If natural (non-man) correspondences can be determined, then the influence of man can be negated or assumed to be dwarfed by the natural influences. If man's influence is not uniform, and of appropriate magnitude, then the correspondences between river conditions and metal concentrations may not be clear.

Conclusions

The assertion of a cause-effect relationship between metal concentrations and river conditions can best be made by dividing the metal ions into two groups: Heavy metals - Zn, Cd, Mn, and the Group I and II (Alkali and Alkaline earth) metals - Ca, Mg, K, Sr.

Group I & II Metals - Ca, Mg, K, Sr

The relationship between these metal concentrations and temperature and discharge have been carefully plotted on graph paper in a previous section.

An examination of the graphs which plot metal concentration against discharge show a general inverse relationship between discharge and metal concentration. As discharge increases, concentration tails off.

The graphs do not exhibit strict adherence to this inverse relationship. But the data does hold true for the most part.

The reasons attributed for this condition is the diluting effect of additional flow in conjunction of what is termed "duration of process". A subtle analogy to this situation can be drawn from a little known story about a Saturday afternoon grocery shopper who requests anonymous identity.

Our shopper, while shopping uncrowded hours, can casually wheel her way down the isles of the grocery store, and gather her select items from the shelves. She can take all the time needed to accomplish

her shopping. She proceeds to the checkout counter, and her groceries are tallied.

The following week, when she returns to the store for her weekly shopping, she is overwhelmed by the amount of people who are also doing their weekly shopping. She scampers for a cart and then enters the flow of shoppers who proceed up and then down the isles at a brisk pace. As she is forced to move with the crowd through the isles, she is sometimes unable to grab her weekly items off the shelves. Sometimes her usual items have been depleted from stock. She is even intimidated or obstructed from going down certain isles because of the crowded conditions. She goes to the checkout counter with the items that she was able to get.

This (shocking) tale helps to explain the diminishing metal contents of water during higher flow conditions. The newly introduced influx of people is analogous to the influx of additional water that can come from direct runoff or from increase groundwater flow. The shopper's story pertains to the notion of duration of process. The effects of dilution are obvious; as water is added, concentrations will lessen. But because this additional water doesn't have the time to work it's processes of solution and extraction of metals from it's surroundings, the marginal amount of metal per each unit of water diminishes.

The relationship between temperature and concentration of the group I and II metals, roughly indicates that as temperature rises, so

does concentration. This relationship is not so pronounced from examination of the temperature vs. concentration graphs, because of the high frequency of exceptions to the rule. From a chemistry stand point, the increase of temperature should be accompanied by an increase of chemical solution. The discrepancies expressed on the graphs, could be attributed to the involvement of other factors such as pH, discharge, plant life, hardness, etc.

The real value of the temperature vs. concentration graphs is that they indicate that temperature doesn't play as large a role in determining metal concentration as does discharge. This is not to say that temperature has no effect; rather, it's effect is not drastic, and can be overshadowed by other factors.

Heavy Metals - Cd, Mn, Zn

Statistical examination of the metal concentration of Cd, Mn, and Zn reveal that Cd was found to range from .02 to .04 ppm; Zn ranged from .10 to .23 ppm; and Mn ranged from .5 to .13 ppm.

These low concentrations seem to follow no pattern. The lack of pronounced variations among these metals, however, beckons the question - Why do the respective concentrations of these metals remain approximately the same despite large variations in discharge.

Date	Discharge (c.f.s.)	Zn Conc.	Mn Conc.	Cd Conc.
10-18	34	.15	.08	.04
11-6	39	.15	.09	.02
11-22	56	.15	.06	.04
12-5	315	.16	.07	.04
12-15	1280	.20	.011	.03

The above data indicates that as the amount of flow is increased,

the concentration seems to stay in step.

The ability of the heavy metal concentrations to remain nearly constant, despite the increased dilution, accompanying higher discharges, says something about the availability of metal source material. This source of metal ions should be responsive and sensitive to the increases and decreases in flow. With this idea in mind, a prime candidate for the source of the metals is the sediment bottom of the river. This is not to say that the sediment bottom wasn't derived from other sources (including man) throughout the drainage basin; rather the sediment river bottom is the source which reacts to compensate for higher discharge.

The increased flow is the mechanism which regulates metal ion involvement with the water.

Webb (1972) compared Zn, Hg, Pb and Cu contents of paired water and sediment samples from 8 different locations along the Ottawa River near Lima, Ohio. His samples were also gathered all on one day. Webb used two extracting agents in preparation for analysis. The first was ammonium acetate, which was used to extract those ions that would be readily available to the environment in a short amount of time. The second extracting agent was a HCl and H_2SO_4 mixture which extracted those ions which might be available to the environment over longer periods of time and exposure.

The results are listed on the following pages.

These tests indicate that the sediment bottom of a river is a source of substantial heavy metal reserves, capable of supplying metal ions to the water in response to discharge fluctuations.

*trace—detectable amount but not measurable

From Webb (1972)

Sample Number	River Water	River Sediment			
		ammonium acetate extracting agent		hydrochloric and sulfuric acid extracting agent	
	mg/l in solution (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)
A	0.000	1.405	13.025	1.491	13.821
B	"	1.000	9.823	1.093	10.733
C	"	0.634	33.700	2.846	151.366
D	"	1.405	10.996	2.591	20.271
E	"	0.754	24.733	1.907	62.538
F	"	trace*	trace	0.533	152.263
G	"	1.076	85.195	1.979	163.514
H	"	0.879	28.732	1.031	33.688

Table IV. Trace mercury content of water and sediment from eight selected sites in the Ottawa River in and near Lima, Ohio.

*trace—detectable amount but not measurable

From Webb (1972)

Sample Number	River Water	River Sediment			
		ammonium acetate extracting agent		hydrochloric and sulfuric acid extracting agent	
	mg/l in solution (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)
A	0.000	0.044	0.412	0.062	0.573
B	"	0.000	0.000	0.068	0.668
C	"	0.477	25.368	0.187	29.641
D	"	0.129	1.013	0.199	1.137
E	"	0.056	1.820	0.195	6.388
F	"	0.077	22.039	0.703	200.985
G	"	0.056	4.587	0.201	16.646
H	"	0.075	2.442	0.129	4.231

Table III. Trace lead content of water and sediment from eight selected sites in the Ottawa River in and near Lima, Ohio.

From Webb (1972)

*trace—detectable amount but not measurable

Sample Number	River Water	River Sediment			
		ammonium acetate extracting agent		hydrochloric and sulfuric acid extracting agent	
	mg/l in solution (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)
A	trace*	0.051	0.476	0.286	2.655
B	"	0.051	0.505	0.334	3.276
C	0.002	0.122	6.510	0.214	11.369
D	trace	0.187	1.466	1.015	7.943
E	0.002	0.471	15.450	0.649	21.294
F	0.004	0.332	94.971	4.710	1345.660
G	0.113	0.091	7.485	0.405	33.452
H	0.059	1.854	60.578	3.774	123.338

Table V. Trace zinc content of water and sediment from eight selected sites in the Ottawa River in and near Lima, Ohio.

*trace—detectable amount but not measurable

From Webb (1972)

Sample Number	River Water	River Sediment			
		ammonium acetate extracting agent		hydrochloric and sulfuric acid extracting agent	
	mg/l in solution (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)	mg/l in solution (ppm)	mg/l in dry sediment (ppm)
A	0.000	0.028	0.255	0.043	0.394
B	"	trace*	trace	0.013	0.130
C	"	"	"	0.006	0.298
D	"	0.011	0.090	0.021	0.164
E	0.002	trace	trace	0.010	0.325
F	0.000	"	"	0.014	0.843
G	"	0.028	2.276	0.037	4.181
H	0.011	0.010	0.324	0.016	0.444

Table VI. Trace copper content of water and sediment from eight selected sites in the Ottawa River in and near Lima, Ohio.

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